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THE MRF/GDAS PRE-IMPLEMENTATION TEST

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REPORT ON THE MRF/GDAS PRE-IMPLEMENTATION TEST
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Introduction

Prior to the implementation of the new Global Data Assimilation System (GDAS) and the new Medium-range Forecast Model (MRF86) on May 30th of this year, a shakedown evaluation was done using a real-time system, run in parallel to the previously operational data assimilation system and medium-range forecast model (MRF85). Additionally, a set of experimental 5-day forecasts were produced using the MRF86 based on initial conditions taken from the summer of 1985; also available was a comparative 30-day integration for a Dec. 85 data set. This paper reports the results of the evaluation and outlines some of the additional development work needed to make improvements to the new system within the next few months.

During the previous year, the basic components of the new systems were individually evaluated with generally positive results, but some facets of the system were not examined in the detail a conservative approach would require. The shakedown, or pre-implementation, test served as an opportunity to determine if it was safe to proceed with operational implementation. It is clear that the decision to implement the new systems was based on an overall favorable outcome of the tests. We are nonetheless aware of several aspects of the system which need further work, and these areas are included in the subsequent discussion.

The New GDAS

The data assimilation system used operationally, prior to the implementation of the new GDAS, possessed many characteristics which had become obsolete. The short range (6 hr) predictions made as part of the system were carried out with the rhomboidal 30, 12-layer version of the NMC Global Spectral Model (Sela, 1982). That model had been displaced in the production of medium-range forecasts in April 1985 by the MRF85 model. The MRF85 incorporated a much more complete suite of diabatic physical process parameterizations, referred to as the "E-2 physics package", derived from techniques used in the models of NOAA's Geophysical Fluid Dynamics Laboratory. It seemed necessary to upgrade the model used in the GDAS to a level consistent with the medium-range forecast model.

Early in 1986 we evaluated the use of the MRF85 model within the GDAS and found it to have a positive impact on medium-range forecasts based on data for 10 cases from January 1985. We also determined that the short-range forecasts from the test system eliminated a nagging problem associated with low-level pools of cold air which had become a recurring feature of the wintertime first guess fields provided to the regional analysis-forecast system.

As noted below, the development work on the medium-range forecast model had proceeded and some clear improvements were incorporated in a revised model referred to as MRF86. Thus it was appropriate to incorporate this revision in the new GDAS. Consequently the test results reported in this paper reflect the use of the same global forecast model in both the GDAS and medium-range predictions.

In addition to the change of the forecast model used in the new GDAS, several significant modifications were made to the analysis system itself. From a programming perspective, the most notable was the inclusion of a vectorized algorithm for the solution of the system of equations which determine the weights assigned to observations. Developed in collaboration with Roy Wessel of ETA Inc., the new algorithm constituted a major step in the optimal use of the Cyber 205 's computational speed for analysis.

This significant gain in computational speed permitted the introduction of some additional resolution in the analysis, the application of a new method for selecting data based on the full set of horizontal correlation functions, and an increase in the maximum number of observations determining the analysis at each gridpoint.

A complete description of the new GDAS will be prepared later this year.

The MRF86

Work directed toward the improvement of the medium-range forecast model continued uninterruptedly after the introduction of the original MRF model in April of last year. The need to improve the model's performance was emphasized by the augmentation of the model used by the ECMWF in May of 1985. Our model's summertime skill lagged well behind that of the European model.

Building on the basis of the GFDL physics packages included in MRF85, several enhancements had reached a sufficiently advanced stage to motivate us to apply them operationally without waiting completion of our planned longer term goals. The principal changes that differentiate MRF86 from MRF85 are:

1. A change in vertical distribution of the model's eighteen layers incorporating greater resolution near the ground in order to improve the physical consistency of the boundary layer parameterization.
2. A modification of the latteral diffusion operator in order to achieve more nearly horizontal diffusion.
3. An adjustment of the sea surface temperature field near coastlines in order to overcome a problem induced by the spectral representation of orography.

4. The introduction of a parameterization of shallow cumulus convection following the method found useful at ECMWF.

5. The generalization of the vertical eddy-diffusion parameterization to sensible heat and the introduction of a stability dependence in the formulation of the eddy-mixing coefficients. The dry-adiabatic adjustment process was deleted.

6. The modification of the Kuo deep cumulus convection parameterization primarily to match the change in vertical structure of the model (see 1. above) and to permit the extension of the convective release of latent heat throughout the troposphere where the environmental parameters indicate this is appropriate.

We also took this occasion to incorporate some improvements to the so-called fixed fields used in the model. Specifically, the surface roughness parameter was modified to reflect the spatial variation in surface vegetation characteristics following the work of Baumgartner, Mayer and Metz (Meteorol. Rdsch. , 1977, pp. 43-48). The surface albedo was modified to reflect the work of Matthews (NASA Tech Memo 86199, 1985) which gave more reasonable values for the world deserts and provided a basis for defining a monthly climatological field. Similarly, monthly climatological fields for Sea Ice, Snow Depth and Soil Moisture were formulated based on information received from GFDL and NASA (GLA).

The further development of the MRF model is expected to continue and an outline of the principal efforts is given subsequently. We also anticipate the production of a documentation of the model latter this year.

The remainder of this report was constructed from contributions by the individuals whose names are appended beneath the appropriate sections. The conduct of the work was a coordinated effort by most of the MRMB staff, with lead roles played by Drs. Dey and Sela. The very satisfactory performance of the parallel mode and the smooth implementation of the new system were due in large measure to the efforts of A. J. Desmarais. The implementation effort also extended to the staff of the Automation Division, particularly Dr. J. Stackpole and J. Irwin and their co-workers. We also received support from personnel of the CAC, in particular Dr. V. Kousky and J. Janowiak.

In concluding this introduction I recall a boyhood motto:
"AD ASTRA PER ASPERA"

Problems Encountered:

During the execution of the pre-implementation test, several changes were made that affected the observed data used by the GDAS. Most of these changes were motivated by operational concerns, not directly related to the conduct of the test. In particular, a problem was detected with the SATEM data that was apparently caused by a change to the NESDIS processing system. This difficulty led to the degradation of the operational and experimental analyses and first-guess fields in the Southern Hemisphere. As noted below, action was taken to block-out the erroneous SATEM data and to insure the use of the available radiosonde reports.

During the conduct of the experiment, a deficiency was noted in the parallel-mode GDAS involving the apparent loss of surface ship data. It was determined that this problem was related to the limited size of the program's data buffer and the significantly greater number of satellite data accessed by the experimental system in order to use satellite data over land as well as sea. Expansion of the data buffer cured this problem.

In the course of conducting the assessment of the performance of the experimental GDAS, we were forced to recognize that both the operational and experimental analyses were being significantly degraded by our use of highly erroneous radiosonde reports in the area covered by WMO blocks 42 and 43. Since the GDAS data quality controls are apparently inadequate to effectively prevent the negative impact of these data, we had recourse to a manual editing of these data by monitoring analysts in the Meteorological Operations Division.

On April 28th, the experimental GDAS failed due to the excitation of a program stop command issued by a routine in the radiation calculation. Investigation of the cause of this failure led to the recognition that the physical parameterizations employed in the MRF model do not adequately bound the temperature field in the uppermost layers of the model atmosphere. While it was possible to "engineer" a corrective fix to the immediate problem, by changing the method used to interface the radiation computation with the prediction model, it remains necessary to develop a rational procedure to bound the excursions of the model upper stratosphere from climatologically determined reality.

SATEM Problems

On April 15, NESDIS made major changes to the procedures used to convert radiance measurements to temperature soundings. The intent was to increase the number of soundings in areas with large temperature gradients, but apparently some bugs crept into the system of complex programs used for the temperature retrievals.

The most important error caused all "cloudy" retrievals over water, south of 45 degrees South, to be incorrect. The effect in the GDAS was the rejection of a large number but not all of the erroneous data. The bad reports which escaped detection had a very adverse impact on the analyses over the vast southern seas and led to the prediction of remarkable and erroneous circulations. In time, the first-guess field was so bad that it was impossible for accurate radiosonde reports from the west coast of South America and Antarctica to bring the GDAS atmosphere back toward reality.

NESDIS was successful in eliminating the problem on May 15th, but another difficulty was then revealed. The microwave-only soundings produced by NOAA 6 were much too cold in the region south of 60 degrees South. Once again, the GDAS reacted by rejecting large numbers but not all of those soundings. NESDIS conducted an investigation of this problem and discovered that in fact random errors were present in NOAA 6 retrievals at all latitudes. Based on that information, it was decided to exclude NOAA 6 SATEMS entirely from both the operational and experimental GDAS systems. This action was taken on May 29th after the pre-implementation test was concluded.

At the present time, the universal random error in NOAA 6 has been eliminated, but the cause of the cold bias in the south polar region remains uncorrected. For completeness, we note that less severe difficulties with SATEM data existed during the period May 1st through May 6th. In that interval, satellite data coverage was sporadic and some inaccurate reports were produced according to information provided by NESDIS.

C.H. Dey

Upper-level Problems

The new GDAS has manifested a number of problems at the upper levels. At 100 mb, the first guess wind field verifies poorly when compared with rawinsonde data over North America. Similarly the 70 and 50 mb first guess wind field displays large "cross-contour" flow with a tendency for too strong southerly winds on the western slope of the Rocky Mountains especially near Mexico. We find similar incredible ageostrophic wind circulations in the analyses on the southern flank of the Himalayan Plateau.

In addition to these problems with the high level wind field, the temperature field in layer 17 of the prediction model is quite unrealistic. Over the tropics the temperatures appear to be almost 20 degrees too cold. The temperatures in the 16th and 18th layers are more reasonable.

Diagnostic studies reveal that the analysis process aggravates the problems with the first guess field, but that the subsequent initialization and forecast prevent further degradation of the first guess. It appears that the strange structures are in some sort of perverse equilibrium.

These problems are presently being explored using a two-dimensional analogue of the transformations between the sigma and pressure coordinate representations of the model atmosphere. It has been possible to simulate the development of pathological thermal structures within the two dimensional framework. Furthermore, it has been found that the use of a modification of the sigma-to-pressure interpolation has beneficial effects in the suppression of the strangely cold layer 17 temperatures. Because of the magnitude of these problems additional work will be conducted with high priority.

B. Ballish

Satistical Results:

Summer cases

Over a period of about a year, changes in the model were tested individually or in small groups by means of parallel runs in which the operational model and a current experimental version were run using the same analysis. Before the final pre-implementation tests, a slightly different evaluation was performed: all of the proposed model changes that had been tested and found useful were combined into one package and this new model was tested on a selection of eight cases from June, July, and August of 1985. The cases were spaced through the three months to sample a variety of northern hemisphere summer synoptic regimes which posed a range of difficulty as judged by the skill scores computed operationally. The test forecasts were run to five days starting from the operational analyses, and were compared to the operational forecasts in the region 20 to 80 degrees North.

Two statistical yardsticks were used - an anomaly correlation (AC) score and a root-mean-square error (RMSE) score. It was found, from the results tabulated below, that while the test model's performance didn't satisfy the usual (95% confidence) statistical criterion for superiority, it did outperform the operational model by day five at both the 1000- and 500- millibar levels and for both scores. Its skill relative to the operational was especially noteworthy in the case of the 500 mb AC score, which came out better in each of the eight cases.

Parallel tests

Following the tests on the summer cases, a complete parallel system was implemented, so that for the first time, the experimental model could be run from initial conditions arising from its own analysis-assimilation system (with a first guess based on its own model physics) rather than from the operational system. The statistics that follow are for forty-six cases in April and May 1986 for which scores from both models were available. The AC scores were done in the same was as for the summer tests, but the RMSE scores were computed for the region from 10 degrees North to 80 North. It should be remembered that the statistics compare not forecast models alone, but two entire analysis-assimilation-forecast systems.

The table below shows that again, the experimental system was superior at day five in all categories. A difference-of-means t-test for thirty degrees of freedom indicates that the results of the 500 mb RMSE score were highly significant; the other three categories did not show a high level of significance. The "win-vs-loss" numbers were also significant only for the 500 mb RMSE scores, because of lack of case-to-case independence, exemplified for instance by a streak of eight consecutive wins for the experimental forecast AC at the very beginning of the test period.

Future Work:

Effort should be devoted to looking into the following areas:

1. The effects upon the statistical scores of the inclusion of zonal wave number zero in the fields being verified.
2. The causes of sudden isolated fluctuations that have been observed in the scores.
3. The dependence of skill scores on general circulation regime.
4. The behavior of the scores over limited data-rich areas, such as North America, and over data-sparse areas.
5. Derivation of skill scores based on verifications taken from soundings, rather than analyses.

P. Caplan

EIGHT SUMMER CASES

ANOMALY CORRELATION

	1000 MB 1	2	3	4	5		500 MB 1	2	3	4	5
DAY	1	2	3	4	5		1	2	3	4	5
OPN	87.2	77.3	69.9	57.0	43.7		95.3	86.6	81.6	72.4	59.4
TST	89.5	81.9	73.2	63.0	50.4	M	94.9	86.5	80.2	72.0	60.8
T-O	2.3	4.5	3.3	6.0	6.7		-0.4	-0.1	-1.4	-0.4	+1.4
OPN	4.2	9.9	9.0	15.9	30.0	R	1.8	8.3	8.8	7.3	19.6
TST	2.9	9.8	8.2	13.5	30.4		2.4	11.2	12.4	14.6	26.1

Mean value of anomaly correlation (M), and the difference (t-o) between the operational (opn) and test (tst) models for the 8 summer cases. Also shown is the range (R).

RMSE

	1000 MB 1	2	3	4	5		500 MB 1	2	3	4	5
DAY	1	2	3	4	5		1	2	3	4	5
OPN	21.9	29.4	33.7	39.6	44.9		18.9	30.9	36.5	43.6	52.1
TST	19.7	25.7	31.8	37.3	42.3	M	19.6	30.7	36.9	43.7	51.6
T-O	-1.2	-1.7	-1.9	-2.3	-2.6		+0.7	-0.2	+0.4	+0.1	-0.5
OPN	5.8	10.2	9.7	14.4	11.9	R	5.4	15.2	13.0	22.8	21.5
TST	5.0	12.5	11.1	13.3	11.7		3.0	10.7	9.8	19.6	21.4

Mean value of the root-mean square error (M), and the difference (t-o) between the operational (opn) and test (tst) models for the 8 summer cases. Also shown is the range (R) of the scores.

PARALLEL TESTS -DAY 5 SCORES
46 CASES

	ANOMALY CORRELATION 1000 MB	ANOMALY CORRELATION 500 MB		ROOT MEAN SQUARE ERROR 1000 MB	ROOT MEAN SQUARE ERROR 500 MB
OPN	50.1 (12.2)	66.7 (8.4)	X(S)	51.4 (5.2)	77.7 (5.9)
TST	53.1 (16.0)	67.6 (9.8)		50.6 (6.2)	69.3 (7.0)
T-O	+3.0	+0.9		-0.8	-8.4
	1.03	0.49	t-score	0.73	6.21
T,O	25,10	24,14	"WINS"	18,12	36,4

Results for the pre-implementation parallel tests during April & May 1986. Operational model scores (opn) and test model scores (tst): X is mean, (S) is standard deviation. T-O is the difference. Significance of the mean difference between paired forecasts is measurable by the t-score. The number of "wins" for test and operational is recorded (T,O).

Forecast Systematic Errors:

Systematic errors from three tests comparing MRF85 and MRF86 forecasts have been calculated and examined. MRF86 forecasts contain less systematic error in height and temperature fields, primarily in the upper troposphere between 40 degrees North and South.

The three tests are:

a) 30 day integrations of the MRF85 and MRF86 <u>models</u> from 12Z 15 Dec. 1985,
b) seven 5-day forecasts with the MRF85 and MRF86 <u>models</u> from selected dates in the summer of 1985, and
c) parallel 5-day forecasts with the MRF85 and MRF86 <u>systems</u> in April and May 1986.

The first two tests were run from the same operationally produced analyses. The last set of forecasts were run from different analyses: the MRF85 runs were made from analyses prepared using a first guess obtained from the operational global data assimilation system; the MRF86 runs were made using analyses produced by the new global data assimilation system that incorporated the MRF86 model as its forecast component.

May 1986 test

The discussion below is based on mean fields verifying May 7-20. Results from mean fields verifying April 6-26 were quite similar.

Differences in the initialized analyses from the two systems usually resembled differences in the un-initialized analyses. However, the two initializations produced rather different effects on the zonal mean temperature field:
a) initialized zonal mean temperatures at the tropical tropopause are 17 degrees Celsius colder in the new system than in the old system; un-initialized tropopause temperatures were only 2 degrees colder in the new system. Five-day forecasts of the tropical tropopause were 13 degrees colder in the new system.
b) the new initialized analyses at 150 mb were 3 degrees warmer and the warming extended to 300 mb. Before initialization the difference was less than 0.5 degrees.
c) the new initialized analyses were also warmer in the lower troposphere, where the new un-initialized analyses tended to be colder.

The initialization in the old system appeared to damp the tropical divergent circulations in the upper troposphere. The new initialized analyses show much stronger upper-level outflow from the Hadley cell than the old initialized analyses.

The new initialized analyses show much stronger horizontal divergence at 150 mb in the tropics and resemble the un-initialized divergence and satellite observations of out-going, long wave radiation much more than the old initialized analyses. The new analyses show strong upper-level convergence along the east coast of Africa, and the west coasts of Mexico and South America, regions of strongly sloping orography.

Systematic forecast errors showed the following zonal mean characteristics:

a) The MRF85 shows a strong cold bias near the tropical tropopause. The MRF86 almost eliminates this cold bias below 200 mb. At 5 days, MRF86 temperatures are nearly 5 degrees Celsius warmer at 250 mb and 5 degrees North. This warming is strongest between 150 and 500 mb and occurs largely between 40 degrees North and South.

b) The MRF86 reduces a cold bias near 700 and 850 mb between 30 degrees North and South from 3 degrees to 2 degrees.

c) Cooling over Antarctica appears more intense in the MRF86 and appears in the new un-initialized analyses as well.

d) A cold bias in high northern latitudes may be slightly stronger in the MRF86.

e) Negative height biases at 500 mb are reduced by a factor of two between 40 degrees North and South, while negative height biases at 250 mb are reduced by a factor of three in the same latitudes in the 5-day forecasts.

f) Zonal winds are nearly 5 m/s more westerly near 40 degrees North and 35 degrees South at 150 mb and more easterly in the upper tropical troposphere in the MRF86 forecasts, which also display more westerly winds over the coast of Antarctica. Differences between the new and old analyses are similar in pattern, but somewhat smaller in magnitude.

g) The MRF86 1-day forecasts show more outflow from the Hadley cell at 150 mb and less at 300 mb. The 5-day forecasts show more outflow at 200 mb in the MRF86, but the difference between the two models is less than at 1-day.

h) The forecast relative humidity is greater at 850 mb in the MRF86, but less above 850 mb. Similar differences were seen between the old and new analyses.

Systematic forecast errors showed the following regional characteristics in the two models over the Northern Hemisphere:

a) 5-day forecasts of 1000 mb height showed similar errors in the two models. The MRF86 model's heights are lower equatorward of 30 degrees North and higher poleward of 30 degrees North, particularly in the one day forecasts.

b) At 250 mb the MRF86 height forecast shows much less negative bias south of 30 degrees North, and a small reduction in the magnitude of systematic errors in mid-latitudes. The patterns in mid-latitudes are very similar in the two models.

c) Low-level temperature fields at 700 and 850 mb in the MRF86 show less cold bias over the Northern Hemisphere oceans, which are up to 3 degrees Celsius warmer at 700 mb over the Pacific than in the MRF85 forecasts.

d) 850 mb temperatures are warmer over the tropical continents in the MRF86 forecasts.

e) The MRF86 5-day forecasts of 250 mb zonal wind show slightly larger errors and westerly bias near 30 and 40 degrees North. Both models forecast the positions of the major jets fairly well.

f) As in the old and new analyses, the MRF86 forecasts are much more moist over the tropical and subtropical oceans and drier over the sub-tropical continents.

The tropical circulations showed the following differences in the two forecasts:

a) The MRF86 forecast a weaker Somali jet over the Arabian Sea at 850 and 1000 mb, and weaker trades at 1000 mb over the Pacific. The strength of the Somali jet was better forecast by the MRF85 5-day forecasts.

b) The upper-level tropical winds are better forecast in the MRF86.

c) The MRF86 5-day forecasts show less intense divergence patterns at low levels in the tropics. The MRF86 shows less convergence at the Equator in the Pacific at 1000 mb but more at 850 mb.

d) The MRF86 5-day forecasts show much less divergence and convergence at 300 mb and more accurate patterns of divergence at 150 mb. The MRF85 forecasts displayed concentrated centers of divergence at 150 mb while the MRF86 forecasts showed broader centers of divergence more in agreement with satellite observations of out-going long-wave radiation. The MRF86 forecasts, however, substantially underestimated divergence in the Indonesian region.

Summer 1985:

The seven 5-day summer forecasts showed differences between the two models that were similar in pattern to, but smaller in magnitude than those found in the May parallel run. For example, MRF86 forecast zonal mean temperatures near the tropical tropopause were 3 degrees warmer than MRF85 forecasts. In May, they were 4.6 degrees warmer. The magnitude of systematic errors in MRF85 forecasts appeared smaller in the seven summer cases than in May.

MRF85 forecasts of 1000 mb height showed negative biases over Japan, Europe, the Mediterranean and off the west coast of the United States. The MRF86 forecasts showed substantially less error in these locations. At 250 mb, the MRF86 displayed less negative bias nearly everywhere than the MRF85 model. Both models, however, forecast a much deeper trough off British Columbia than was observed, too much of a ridge over the northwestern U.S., and too deep a trough over eastern Canada;

this was a consistent pattern seen throughout the summer of 1985 in the MRF85 model. Forecast 850 mb temperatures in the MRF86 displayed less cold bias over the oceans, but greater warm bias over the continents.

The MRF86 appeared to depict the 150 mb tropical winds better, showing more agreement with the observed pattern in the northerly flow over the Indian Ocean out of the Asian anticyclone and in the troughs over the northern sub-tropical oceans. Neither model, however,showed strong divergence over the Asian monsoon region at 150 mb. Both models displayed too strong anticyclones located too far north over North America, even though the upper level divergence over Mexico in the MRF86 forecast agreed much better with the analyzed divergence than did the MRF85 forecasts

<u>December 1985</u>:

The MRF86 model displayed a larger average error in the zonal mean wind, shifting the Northern Hemisphere jet 5 degrees poleward from its observed position and showing a much stronger mid-latitude westerly bias than in the MRF85 model. The MRF86 model maintained the observed strength of the stationary eddies, unlike the MRF85
model. Rising motion in the tropics extended higher into the atmosphere in the MRF86 model than in the MRF85.

The MRF86 average forecast of 1000 mb height generally shows better agreement with the observed, except over the Sahara where MRF86 heights are too low. At 250 mb the MRF86 forecast better captures the amplitudes and phases of the observed troughs and ridges than the MRF85, which weakens the amplitudes. The MRF86 model reduces the negative tropical bias by a factor of two and produces a zonal pattern of average error, with positive biases near 30 degrees North and negative biases over the Arctic and Europe. The MRF85's systematic error resembles a wavetrain stretching from Hawaii across North America to the Atlantic. The pattern of systematic error in the 250 mb zonal wind is also more zonal in the MRF86 model, displaying westerly biases between 30 and 60 degrees North and easterly biases equatorward of 30 degrees North.

In the tropics the MRF86 average forecast shows more low-level convergence over tropical land masses north of the equator than observed or forecast in MRF85. At 150 mb, the MRF86 model better forecasts the strength of the Pacific anticyclones and the position of the South American anticyclone than the MRF85 model. The MRF85 displays concentrated centers of divergence at 150 mb near regions of steep orography. The MRF86 forecast shows broader centers of upper-level divergence, more in agreement with analyzed divergence and out-going long-wave radiatioon. Upper-level divergence over Indonesia, however, is much less in the MRF86 forecast than in the analysis.

Systematic Differences Between Analyses:

Systematic differences between the old and new analyses were studied over two months of parallel runs. Mean differences between the old and new analyses were calculated for each of nine 4- to 6- day periods between 24 March and 18 May, using analyses prepared every six hours. The differences in all nine periods proved to be quite similar.

The strongest change occurred over Antarctica. The old analyses tended to show a ridge over Antarctica unlike analyses by other operation centers. The new analyses showed much colder temperatures over Antarctica and much less of a tendency for an Antarctic ridge.

Other zonal mean differences included:

a) colder temperatures at 100 mb over the tropics by 2 to 2.5 degrees in the new analyses;
b) more westerly zonal winds at 150 mb in the new analyses by up to 3 m/s between 40 North and South;
c) stronger outflow in the upper troposphere in the Hadley cell in the new analyses, with stronger in-flow at 850 mb and weaker inflow at 1000 mb; and
d) maximum relative humidity at 850 mb in the new analyses rather than 1000 mb as in the old analyses.

The largest differences in the Northern Hemisphere troposphere occurred over the Sahara Desert, where 1000 mb heights were lower by as much as 70 m in the new analyses, 850 mb temperatures were warmer by 2 to 3 degrees and 700 mb temperatures were colder by 2 degrees. Similar differences occurred over the other tropical land masses. Differences in the two analyses of 250 mb height were less than 50 m everywhere in the Northern Hemisphere. At 850 mb the new analyses show considerably more moisture over the tropical and sub-tropical oceans and somewhat drier conditions over the subtropical continents.

The old analyses showed very weak 1000 mb winds at the Equator. The new analyses featured stronger trade winds at 1000 mb over the Equator in the Atlantic and eastern Pacific, less convergence along the Equator over the oceans and more convergence to either side of the Equator. At 850 mb the new analyses displayed more convergence over the Equator in the Pacific and Atlantic, and stronger convergence over the sub-tropical land masses. The 850 mb winds in the new analyses also showed less tendency to blow through the Andes at the Equator and more of a tendency to be deflected by the Andes. In mid-May the new analyses exhibited a stronger Somali jet over the Arabian Sea. The 300 mb winds showed large differences in the eastern equatorial Pacific. At 150 mb the divergence pattern was stronger and somewhat smaller in scale in the new analyses, and showed better agreement with the out-going long-wave radiation observed by satellite over South America, the Atlantic and Africa.

Many of the differences between the old and new analyses resembled differences betwee the old analyses and the forecasts or differences between the old and new forecasts, implying that differences in the two analyses reflect differences in the first guess fields rather than differences in the selection and treatment of data by the two analysis systems.

Future Work:

A more comprehensive report on the systematic differences in the analyses and systematic errors in the two systems will be prepared subsequently.

G. H. White

Comparison of the New and Old GDAS:

This is not a comprehensive evaluation, but rather a subjective comparison of the new and old GDAS based on the inspection of a few components of the assimilation systems. The largest differences between the old and new systems appear to be manifested in the divergent component of the wind at 200 mb and in the low-level vector wind field. Temperatures at mid-latitudes in the lower troposphere appear to be 1 to 2 degrees warmer in the new GDAS. Many of the differences that we observed appear to be in regions where the model orography has changed. (Note the MRF86 model used in the new GDAS employs the "silhouette orography" whereas the old GDAS's model used the "mean orography; additionally, the resolution of the silhouette orography is rhomboidal 40 whereas the old model had rhomboidal 30 resolution.) It should be noted that this evaluation was based on initialized analyses, for the month of May, 1986 only.

Plots of the 200 mb velocity potential from both the new and old GDAS revealed the largest differences over the major convective centers: Indonesia, and near-equatorial South America and Africa. In the new system, slightly stronger outflow is observed in the Indonesian region, while a much stronger divergent center is indicated in equatorial South America in the new system. In Africa, the magnitude of the velocity potential is about the same for both systems, but the pattern has changed significantly. In particular, we noted a more compact nature and southward displacement of the center in southern Africa in the new system, and the appearance of a weak center over West Africa.

Examining plots of 200 mb divergence for the new and old GDAS and a plot of "OLR" (Outgoing longwave radiation) valid for May, 1986, showed much more detail (be it real or not) in the new system. Stronger divergent centers are observed in the new system in the western equatorial Pacific and in equatorial South America. An area of upper-level divergence in equatorial Africa in the new system is in marked contrast to the convergence found in the old system. The OLR data supports the new system, particularly over Africa. Over the other two major convective regions, the divergent regions are stronger, and are in better agreement with the areas of precipitation, as inferred from the OLR. In particular, the divergence field from the new GDAS appears to yield a better representation of the ITCZ over the Pacific.

A possible problem with the new assimilation system was noticed when viewing the divergence maps. Wave trains appear to be observed near areas of elevated topography. For instance, we noted a series of altenating convergence and divergence centers beginning near the Andes in South America and extending northeast to southeast Brazil. Similar features are observed emanating from central North America, Mexico and from the Tibetan Plateau. In addition, couplets of divergence and convergence centers over eastern Australia and South Africa appear to be topographically induced. These features are not supported by "OLR" and may be spurious.

Inspection of the difference of the 1000 mb wind field showed increased strength of the equatorial easterlies (about 2 m/s in the central Pacific) in the new GDAS. A tendency for weaker convergence at the equator in the central Pacific is also evident with increased convergence at about 5 degrees North between 100 and 150 degrees West. This is consistent with the observed position of the ITCZ at this time of year. The old GDAS frequently produce a spurious convergence area on the equator. Another noteworthy difference in the 1000 mb wind field appears in the Gulf of Guinea where erroneously strong westerlies had been observed in the old GDAS. A weaker westerly component prevails in the new GDAS. Elsewhere, the diferences appear to be related to changes in topography.

Comparing maps showing the 700 mb temperature difference between the two systems showed that the new GDAS is 1 to 2 degrees warmer in mid-latitudes than the old GDAS, with a notable exception in the Himalayas where the new GDAS is about 4 degrees cooler, presumably due to topographic changes. In the tropics, the new GDAS appears to be slightly cooler, in general, than the old system. In the southern hemisphere the major differences occur over Antarctica where the new GDAS is up to 13 degrees colder than the old system.

No major differences in the 200 mb winds between the two systems were observed, in the northern hemisphere. The largest difference is only 3 m/s. The "dominant" differences appear to be in the form of stronger anticyclonic circulations off both coasts of North America in the new GDAS. In the southern hemisphere a 6 m/s difference was noted in southern Brazil, while a 6 to 12 m/s stronger cyclonic circulation centered at the South Pole is observed in the new GDAS.

With regard to indices that CAC uses for climate monitoring in the equatorial Pacific, no noteworthy differences were observed.

J.E.Janowiak

Planned Development:

Work continues on the enhancement of the performance of the MRF prediction model and on the GDAS. The principal efforts now underway are reviewed in this section.

New GFDL Radiation Code

S. Fels and D. Schwarzkopf of GFDL have rewritten parts of the radiation code and increased its computational efficiency so that the new parameterization will be about three times faster than the current version. A 9-layer version is being used successfully by K. Miyakoda's group. Clear-sky comparison between the code and exact "line-by-line" computations agree to within less than .2 degree/day. The new code adapted for the MRF coordinate system will be made available to us by the end of June 1986.

Diurnal Cycle Approximation

An approximation to the diurnal cycle is proposed which fits into the current structure of the MRF model. Radiation calculations are still made once every 12 hours using latitudinal mean values of the solar zenith angle for shortwave computations. At each model time step, shortwave fluxes and heating rates on the computational grid are weighted by the exact cosine of the solar zenith angle. An attempt is made to adjust the downward longwave flux at the ground during the 12-hour interval, but no attempt is made to approximate changes in longwave heating rates. Comparison of model forecasts with surface observations show the approximation to be reasonable, though the amplitude of the surface (skin) temperature wave may be too weak. Comparison with a forecast in which the radiation calculations are made every hour shows that the errors in longwave heating rates generally compensate over 24 hours.

Zonally Asymmetric Cloud

The MRF model currently uses three types (high, middle,low) of zonal mean stratiform clouds in its radiation parameterization. Cloud fraction is time interpolated from seasonal value, but cloud height and thickness are just taken for the particular season (no time interpolation). Cloud characteristics of albedo, absorptivity, and emissivity are constants.

The six year Nimbus-7 cloud climatology (Stowe, et.al., 1986,6th Conference on Atmospheric Radiation, Williamsburg) will be used to create zonally asymmetric cloud fraction for each month. Cloud heights, thickness, and characteristics will not be modified. Total cloud amount, as seen from the top of the atmosphere, will be computed from MRF zonal mean data assuming random over-lapping clouds. The ration of Nimbus-7 to MRF (zonal mean) total cloud will be used to disperse the Nimbus-7 data into high, middle and low cloud categories.

K.A.Campana

Boundary Layer Modifications

Thirty-day DERF runs have indicated that there are several problems in the PBL physics in the current MRF86 model. Several experimental forecasts focusing on the PBL have shown:

1. Very large amplitude oscillation of predicted variables with a period of 4 time steps, due to the very thin layers used in the model PBL in combination with the stability dependent vertical diffusion.
2. Formation of very strong inversions in the PBL in the synoptic situations characterized by strong warm air advection over snow covered land.
3. Excessive warming over subtropical dry land.

The 1st problem is shown to be corrected by introducing predictor-corrector type numerical scheme for evaluating the vertical diffusion coefficient. The scheme is expensive but there seems to be no problem with its practical implementation.

Problem 2. can also be solved in large part by using a small value of the roughness parameter Zo (.1 to 1.0 cm) over snow covered land. Further improvements may be achieved by using a newer formulation of the turbulence relations in the stable region.

The 3rd problem seems to be related to the surface heat balance and hydrology formulation. It seems best to delay an attack on this problem until we have introduced the planned modifications of the radiation computation.

M. Kanamitsu

Control of Upper-level Temperature

Because of the limited resolution of the model stratosphere there is little basis for expecting accurate physical balances to be maintained between radiative and dynamical heat fluxes. In longer range forecasts and in the use of the model within the GDAS it seems necessary to control the excursions of the upper-level temperatures from climatologically reasonable values. To achieve this it is proposed to introduce a relatively long-time scale (20-day) diffusion toward climatological temperatures in the models stratosphere.

Triangular Truncation

A version of the MRF86 model has been constructed using triangular spectral truncation. It is planned to evaluate the impact on medium range forecasts of a change in resolution from rhomboidal 40 to triangular 60.

J.G. Sela

GDAS Cycling of Physics

Currently, surface parameters (ground temperature, soil moisture and snow cover) are set to climatological values each time the analysis is performed. It is desirable to examine the possibility of using the predicted values produced by the assimilation model, in conjunction with the spin-up of model physics.

In order to pursue the possibility, several modifications of the model used in the assimilation are required:

1. Restructure the file organization used in the system such that surface fields are easily accessed, modified or merged. This is necessary to prevent the predicted fields departing from reality. It is also desirable to modify the current file structure for future use of analyzed surface fields (ice cover, snow cover, cloud cover, etc.).
2. Monitor the surface field as well as free atmospheric variables as assimilation continues. It is also desirable to monitor the diabatic heating during the course of assimilation.

In addition to these requirements, a number of changes can be made to the codes which will facilitate their use by staff and visiting scientists.

M. Kanamitsu